EFFECT OF BULBOUS BOW ON MOTION OF SHIP: PHASE I

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SYNOPSIS

It is not very long that the great Tsunami had struck the shores of South Asia. A lot of disaster had happened particularly in the field of marine industry. Numerous numbers of ships could not survive this natural calamity. After this incident a large number of search and rescue vessels are needed. Theses vessels require a great deal of stability, safety and speed. With this view in mind, this paper investigates the behavior of motion incorporating different shapes of bulbous bows. It is a generalized fact that the lesser the amplitude of motion the better the resistance, human comfort and ship stability.
A number of researches had been done in studying the resistance characteristics incorporating different bulbous bows. But the effect of bulbous bow on motion had not been studied in detail. In this paper some work has been performed by incorporating various types of bulbous bows. Different types of bulbous bows were designed in three-dimensional (3D) computer aided design (CAD) software. The vessels with their new bows were paneled. A C++ computer program is developed for this paneling purpose. With these new designed bulbous bows the motion characteristics are studied using 3-D source distribution technique in regular wave. It is observed that the bulbous bow influence the motion responses of vessels.

1. INTRODUCTION

Today the bulbous bow is a normal part of the modern sea going vessel. As model experiments show, a ship fitted with bulbous bow can require far less propulsive power because of reduction in resistance and have increased cruise speed; which gives an overall reduction in fuel consumption [1].

The bulbous bow was discovered rather than invented [2]. Before the turn of the century, towing experiments performed in the US with warships established that the ram stem projecting below the water had a resistance decreasing effect. A torpedo boat model showed that an under water torpedo discharge pipe ending in the forward stem also reduced resistance.

A flat board, intended to suppress the bow wave, was fitted by W. Froude [3] to a model of H.M.S. Fury in 1873, "with benefit to the performance". Many clipper ships of the 1850's sailed at speeds where Froude number (Fn) exceeded 0.33. The designers learned that fining the bow at the surface waterline and hollowing it further aft was one method of reducing pressure resistance.

Some interesting tests were conducted by J.G. Thewsin [3] between 1930 and 1932 on a small 2.5ft model in the 30ft model basin at Washington. At first a model without bulb was towed, then a submerged bulb was towed by itself without the model, and finally a model was towed with the bulb attached. By superposing graphically the wave profiles created by the model and bulb alone, a wave profile was obtained which closely resembled that on the model when towed with the bulb attached. The model tests showed a reduction in resistance in certain high ranges of torque, just as had all the previous tests on models of large ships.

A few years later W.C.S. Wigley [3], at the William Froude Laboratory at Teddington, derived mathematical expressions for the pressure resistance due to wave making and the vertical amplitudes in the wave trains. Wigley's analytic work was supplemented and confirmed by model experiments, embodying certain combinations of bulb volume, bulb position with reference to the hull and ship speed.

In 1962, Dr. Takao Inui [4] of the University of Tokyo presented a paper at the annual meeting of the Society of Naval Architects and Marine Engineers in New York City in which the author advanced some remarkable theories and test results of the studies of wave-making resistance. These theories were the result of a number of years of research in the model basin at the University of Tokyo where Inui had developed new and ingenious techniques of analysis. These studies have led through various configurations of bulb forms not only at the bow but at the stern, where the extensions concentrated on wave cancellation and speed augmentation in the moderate to low Froude Number values.

However, in spite of all these efforts the effect of bulbous bow on motion has been ignored and the number of research is also limited. This particular research involves the effect of shape, size, and position of bulbous bow on the motion characteristics due to various bulbous formations. Consequently this paper, as in the initial phase, presents some traditional and also some innovative bulb formation. In this regard, the program developed by Islam [6] is extended and modified for computation of the motion in six degrees of freedom.

2. CHOICE OF VESSEL

In the past a lot of numerical model analysis has been carried out on fuller vessels. Significant works have also been performed in floating bodies with zero forward speed. But analyses on finer vessels are very limited. In fact analysis with forward speed effect is very complex and time consuming. This caused very little work on vessels of fine form. Therefore, as a new thought, a fine ship of block coefficient 0.6 is chosen from Series-60 vessels. The reason that influenced in choosing the Series-60 vessel is the availability of experimental results.

3. DESIGN OF BULBOUS BOW

This study focuses on some traditional as well as on some innovative bulb formations. For simplicity and easy understanding, five different types of bulbous bows, as shown in Figure 1, have been designed:

Shape - 1: Circular Cross-section Dome Nose (CCDN) Type
Shape - 2: Eye Cross-section & Sharp Nose (ECSN) Type
Shape - 3: Triangular Cross-section (TC) Type
Shape - 4: Inverse Triangular Cross-section (ITC) Type

Shape - 5: Sonar Dome (SND) Type

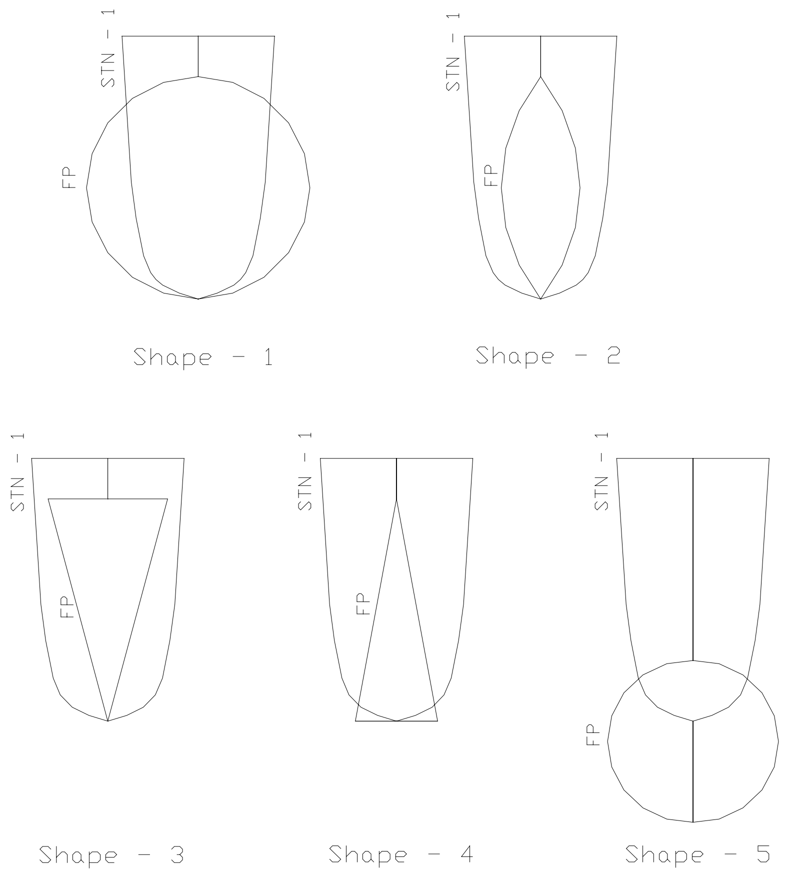


Figure 1: Front view of five different shapes of bulb cross-section

The first two shapes (Shape-1 and Shape-2) are quite common in fuller vessels. Shape-3 and Shape-4 are new concepts and not much seen in the waterways. Shape-5 is more commonly used in Naval Vessels/Warships, which requires sonar dome for the placement of sonar devices.

However, variants of these bows are designed by altering the bulb cross section, position of bulb below load water line (LWL) and length of projection forward of forward perpendicular (FP). Figure 2 shows these the parameters in detail. One of the prime objectives of this research is to find out how the parameters influence the motion of ship. With this view in mind some 27 bulbous bows are designed. Their particulars are shown in Table 1.

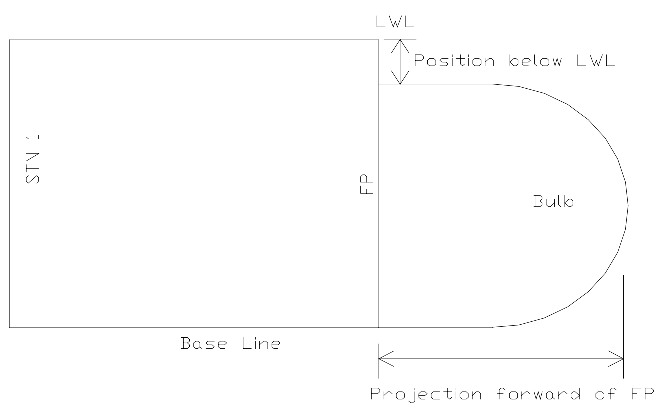


Figure 2: Definition Sketch of bow

Table 1: Particulars of Different Bow Shapes

Bulb Type Group	Code Name	Particulars	
		Position below LWL (m)	Projection forward of FP (m)
Shape – 1 Circular Cross-section Dome Nose (CCDN)	CCDN_D1 CCDN_D2 CCDN_D3 CCDN_p3m_D1 CCDN_p3m_D2 CCDN_p3m_D3 CCDN_p5m_D1 CCDN_p5m_D2 CCDN_p5m_D3	1.0 2.0 3.0 1.0 2.0 3.0 1.0 2.0 3.0	2.75 2.25 1.75 5.75 5.25 4.75 7.75 7.25 6.75
Shape – 2 Eye Cross-section & Sharp Nose (ECSN)	ECSN_D1 ECSN_D2 ECSN_D3 ECSN_p3m_D1 ECSN_p3m_D2 ECSN_p3m_D3 ECSN_p5m_D1 ECSN_p5m_D2 ECSN_p5m_D3	1.0 2.0 3.0 1.0 2.0 3.0 1.0 2.0 3.0	2.0 2.0 2.0 5.0 5.0 5.0 7.0 7.0 7.0
Shape – 3 Triangular Cross-section (TC)	TC_1 TC_2 TC_3	1.0 2.0 3.0	4.0 4.0 4.0
Shape – 4 Inverse Triangular Cross-section (ITC)	ITC_1 ITC_2 ITC_3	1.0 2.0 3.0	5.0 5.0 5.0
Shape – 5 Sonar Dome (SND)	SND_CC_1 SND_CC_2 SND_CC_3	6.0 5.5 5.0	1.0 1.5 2.0

4. METHODOLOGY

The three dimensional surface of the ship is generated in Auto CAD, a common 3-D drawing tool, applying the offset table provided by Todd [5]. Using the AutoCAD surface modeler, which defines faceted surfaces using a polygonal mesh, the ship is paneled over 300 to little over 400 pieces depending on the bulb formation.

The ship is paneled in such a way that each panel consists of four nodes and no two nodes in the same panel have the same coordinate value (i.e. X,Y,Z).The coordinates of all the nodes are obtained in an 'unformatted' form from Auto CAD.

Several computer programs are developed for preparing input files. One called 'PanGen' or Panel Generator is for generating the panel number with their corresponding nodes. It generates rectangular panels and gives output in the text form. Another computer program is developed to format the bulk amount of data obtained form Auto CAD. The purpose of this program is to prepare the files consist of all the information about the coordinates (i.e. nodes) and panels (i.e. elements).

To study the motion characteristics of ship at sea waves with forward speed, a computer program is being developed [6]. This program is based on 3-D source distribution technique and uses panel method, which is also called Boundary Element Method.

Panel methods are the most common techniques used to analyze the linear steady state response in regular waves. One way to distribute sources over the mean wetted body surface. The source technique is commonly used for the calculation of wave loads and hydrodynamic co-efficient for a floating and also for moving body in water.

5. RESULTS AND DISCUSSIONS

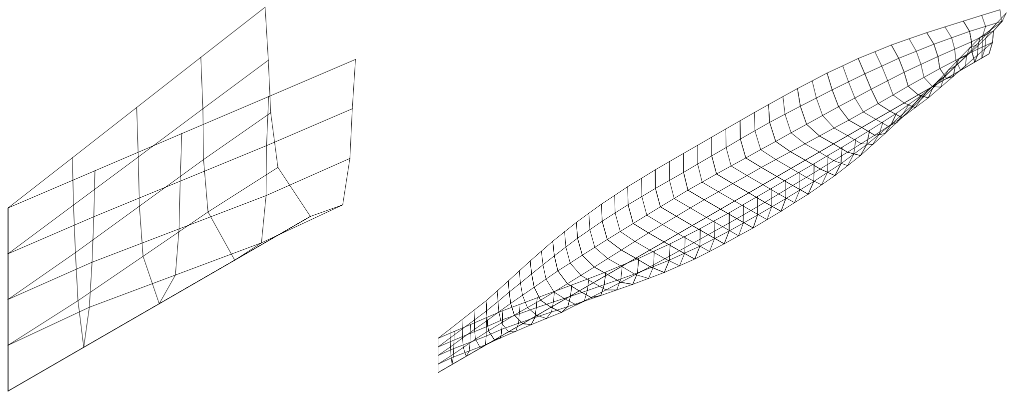
In this particular study three types of bow were chosen for investigation. Figure 3 shows the wire frame drawings of the bows together with that of the total vessel up to load water plane area and from forward end to after perpendicular. It is seen from the figure that the first bow is the original bow without bulb (called Base) and rests are the bows with bulb formations (called CCDN_D1 & TC_1). To understand the effect of circular and triangular cross-sections on motion amplitudes theses two were selected. For this particular study, all the vessels were meshed into four-node panels. The base vessel was meshed into 320 panels, vessel with CCDN bulb into 352 panels and vessel with TC bulb into 336 panels.

Only head sea condition (i.e. encountering angle = 180°) is considered during computation. It is of particular interest of this study to investigate the influence of bulbous bow on high-speed vessels. Therefore, Froude number (Fn) 0.3 is taken through out the computations. Also it was assumed that the encountering waves were small in amplitude.

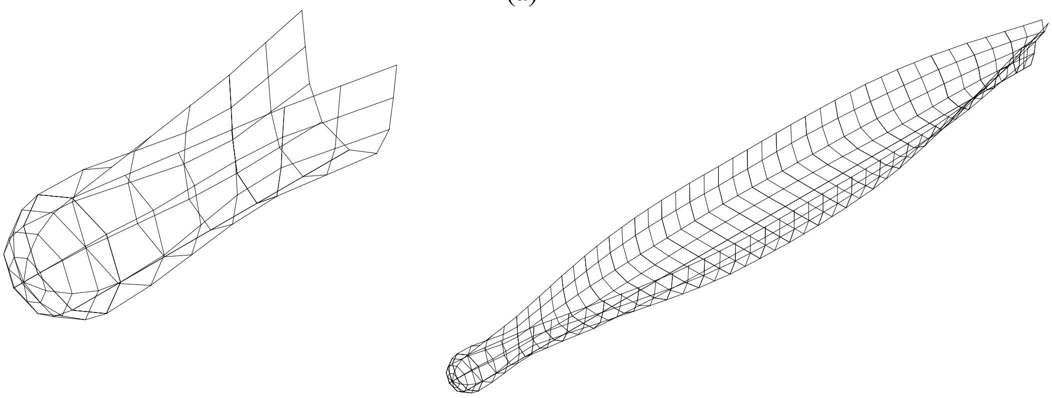
The results obtained in this study show that there are some noticeable changes in the amplitudes of motion, particularly in the region of resonance (i.e. around $\omega_e = 1$). Figure 4 shows the non-dimensional surge amplitude(X_1/ς_a ; ς_a = wave amplitude) against encountering frequency (ω_e). It is seen from the figure that there are no noticeable changes in amplitude until $\omega_e = 0.9$. After that CCDN and TC gets quite separate from each other as well as from the Base. They are quite separable up to $\omega_e = 1.3$. The fact to understand from this result is that adding bulb to a vessel might just increase surge amplitude. But this amplitude is very small (below 0.1). So there is no possible adverse effect.

The non-dimensional heave amplitudes (X_3/ς_a) are plotted in Figure 5 against the encountering frequency. The results are somewhat interesting. Around the region of resonance (say ω_e = 0.9 to 1.1), CCDN produces less heave amplitude than the others do. But in lower frequency region it is slightly higher. For the others (TC and Base), there is not much of change in amplitude all throughout the frequency range.

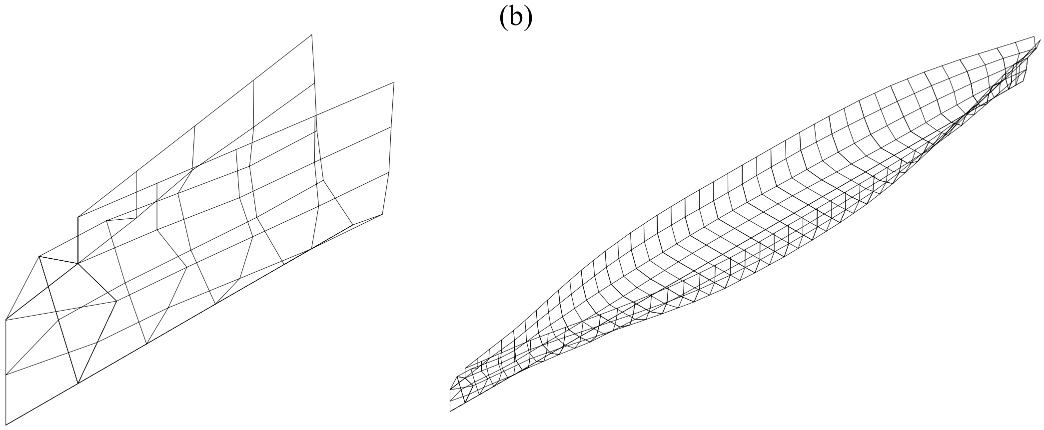
Figure 6 shows the non-dimensional pitch amplitude ($\theta_a/k\varsigma_a$; k =wave number) against the encountering frequency. The results are also interesting as like as the heave. At the lower frequencies, CCDN produces less pitch than the others do. But as the encountering frequency increases, pitch for CCDN increases than others noticeably. Certainly this is quite opposite to the case of heave. It seems although not conclusive, heave and pitch are inversely related by some factors.



(a)



(b)



(c)

Figure 3: Bows incorporated to the original vessel (a) Base, (b) CCDN_D1 and (c) TC_1

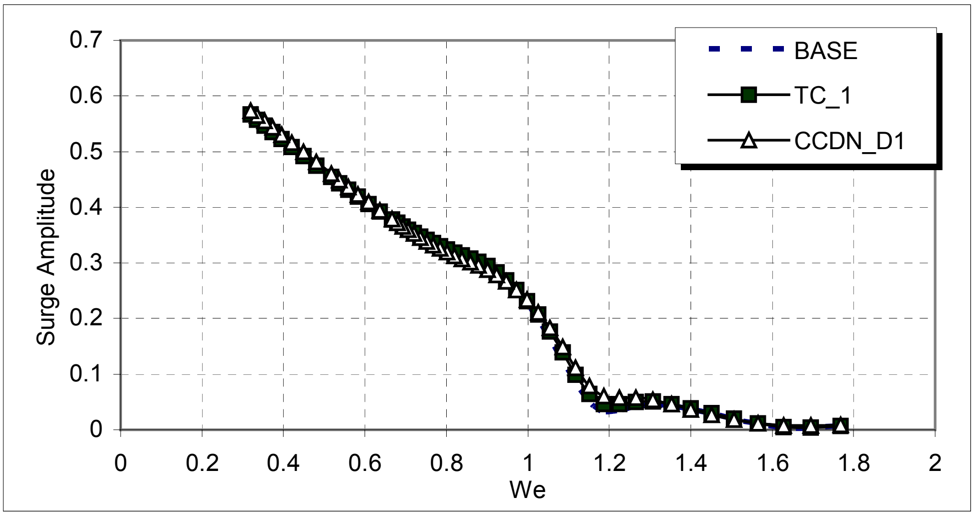


Figure 4: Surge amplitude vs. encountering frequency

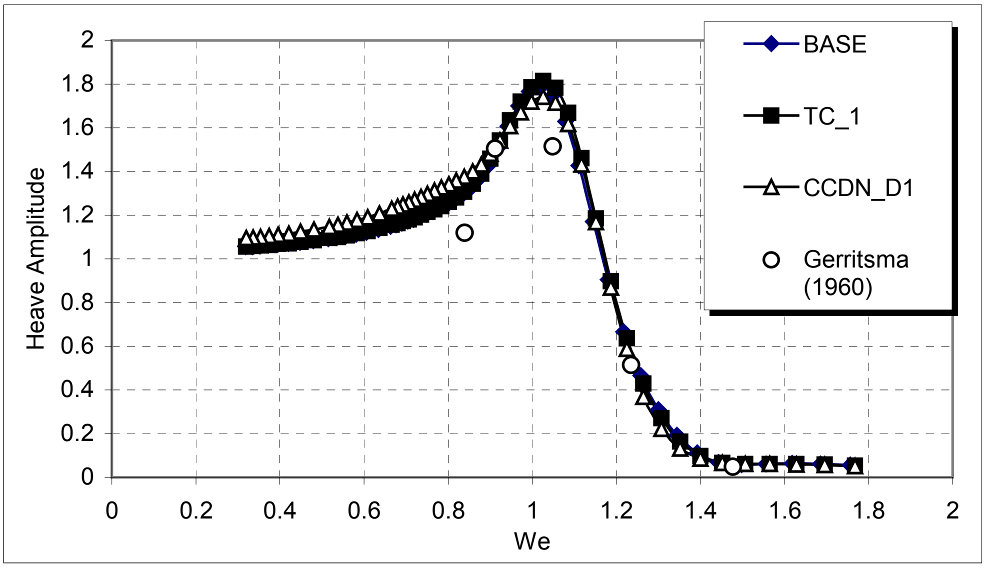


Figure 5: Heave amplitude vs. encountering frequency

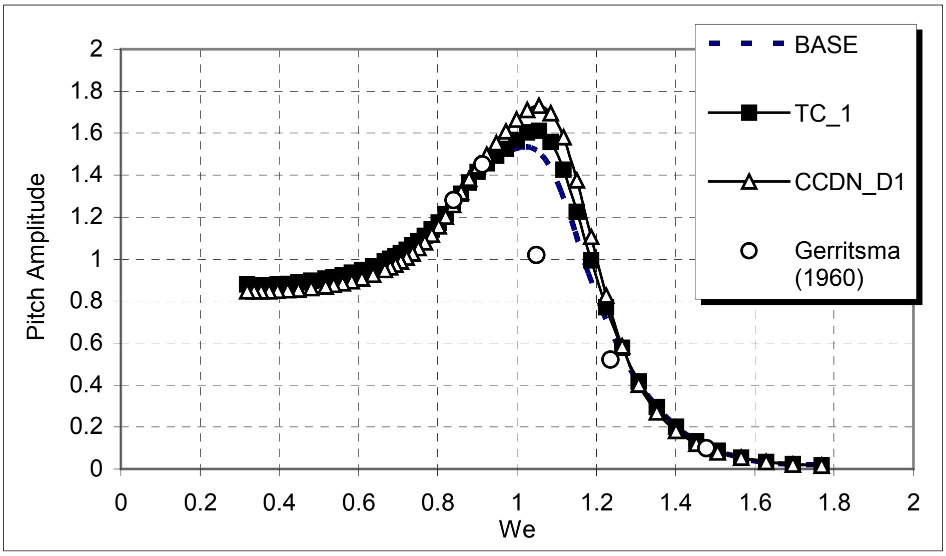


Figure 6: Pitch amplitude vs. encountering frequency

To validate the current study some experimental data of series 60 vessel, as obtained by Gerritsma [8], are plotted in Figure 6 and Figure 7. The comparison between the theoretical model and experimental data are quite satisfactory except for a little discrepancy in the region of natural frequency ($\omega_e = 1.0$). This might be due to very old experimental data and unavailability of sufficient results in that region of frequency.

6. CONCLUSION AND RECOMMENDATIONS

This particular research project is very much in the early stage. This stage is specified as Phase I. Therefore, it is not wise to comment or declare any conclusive statements. Phase I is mainly focusing on the behavior study of different amplitudes of motion (i.e. surge, heave and pitch). Therefore, the prime objective is to obtain as much results as possible. But due to technical limitations the progress is not drastic. In future stages the main focus will be on understanding the physical facts of bulbous bow that dictate the amplitudes of motion.

It is stated earlier that out of 27 bulbs only 3 have been investigated. Therefore, the results are not fully conclusive. On the other hand, in this study Froude number, encountering angle, and wave amplitudes were kept constant. But in the reality these factors vary quite often during a sea voyage. For future investigations these factors have to be considered for conclusive remarks.

Studies of motion of marine vessels are quite complicated and require a great deal of time. A lot of effort has been put in the past to understand the behavior of ship motion at sea. Very few results dictate researchers towards a simple solution. However, keeping this in mind, an extensive and systematic research is recommended.

7. REFERENCES

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